Spherical Coordinate Systems for Streamlining Suited Mobility Analysis

Elizabeth Benson[1], Matthew S. Cowley[2], Lauren Harvill[2], Sudhakar Rajulu[3]

[1]MEI Technologies, Houston, TX, [2] Lockheed Martin, Houston, TX; [3]NASA Johnson Space Center, Houston, TX

Introduction:

When describing human motion, biomechanists generally report joint angles in terms of Euler angle rotation sequences. However, there are known limitations in using this method to describe complex motions such as the shoulder joint during a baseball pitch.

Euler angle notation uses a series of three rotations about an axis where each rotation is dependent upon the preceding rotation. As such, the Euler angles need to be regarded as a set to get accurate angle information. Unfortunately, it is often difficult to visualize and understand these complex motion representations. One of our key functions is to help design engineers understand how a human will perform with new designs and all too often traditional use of Euler rotations becomes as much of a hindrance as a help.

It is believed that using a spherical coordinate system will allow ABF personnel to more quickly and easily transmit important mobility data to engineers, in a format that is readily understandable and directly translatable to their design efforts.

Objectives: The goal of this project is to establish new analysis and visualization techniques to aid in the examination and comprehension of complex motions.

Methods: This project consisted of a series of small sub-projects, meant to validate and verify the method before it was implemented in the ABF's data analysis practices. The first stage was a proof of concept, where a mechanical test rig was built and instrumented with an inclinometer, so that its angle from horizontal was known. The test rig was tracked in 3D using an optical motion capture system, and its position and orientation were reported in both Euler and spherical reference systems. The rig was meant to simulate flexion/extension, transverse rotation and abduction/adduction of the human shoulder, but without the variability inherent in human motion.

In the second phase of the project, the ABF estimated the error inherent in a spherical coordinate system, and evaluated how this error would vary within the reference frame. This stage also involved expanding a kinematic model of the shoulder, to include the torso, knees, ankle, elbows, wrists and neck. Part of this update included adding a representation of 'roll' about an axis, for upper arm and lower leg rotations.

The third stage of the project involved creating visualization methods to assist in interpreting motion in a spherical frame. This visualization method will be incorporated in a tool to evaluate a database of suited mobility data, which is currently in development.

Results: Initial results demonstrated that a spherical coordinate system is helpful in describing and visualizing the motion of a suit. The system is particularly useful in describing the motion of the shoulder, where multiple degrees of freedom can lead to very complex motion paths. When it is desired to present motions in terms of anatomical planes, this analysis method will break motion paths into specified regions like flexion/extension and abduction/adduction. A spherical reference frame also facilitates describing work envelopes.